Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

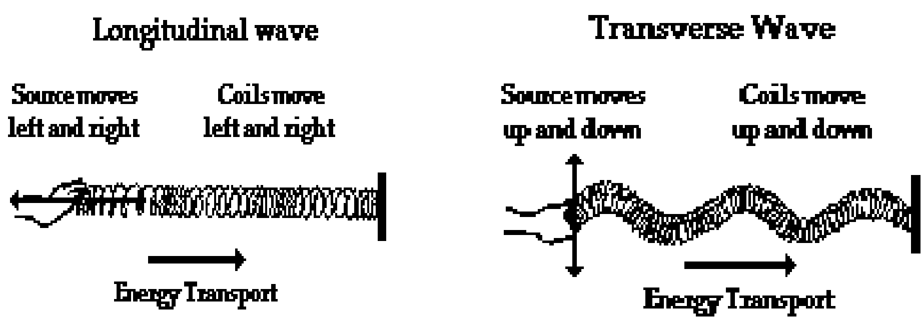
PS-7.1 Illustrate ways that the energy of waves is transferred by interaction with matter (including transverse and longitudinal /compressional waves).
Taxonomy Level: 2.2-B Understand Conceptual Knowledge

Key Concepts:
Wave, Transverse wave, Longitudinal/Compressional wave
Medium
Energy transfer

Previous/Future knowledge: In 8th grade students recalled that waves transmit energy but not matter (8-6.1). In Physical Science students will give examples of waves transferring energy without transferring matter through transverse and longitudinal/compressional waves.

It is essential for students to
- Understand that a wave is a repeating disturbance that transfers energy through matter or space.
  - Wave motion always transfers energy, but not matter from one place to another.
  - When a wave moves through matter, the matter is disturbed so that it moves back and forth, but after the wave passes, the matter will be in about the same position that it was before the wave passed.
- Give general examples of various waves, illustrating, with diagrams or descriptions, the direction of the disturbance and the motion of the particles of the medium in each. Each illustration should:
  - Describe the energy (light, sound, mechanical disturbance, etc);
  - Describe the direction and the path that the energy takes;
  - Identify the medium, if any;
  - Describe the direction that the particles of the medium are disturbed as the wave passes;
  - Describe the position of the particles of the medium before and after the wave passes.

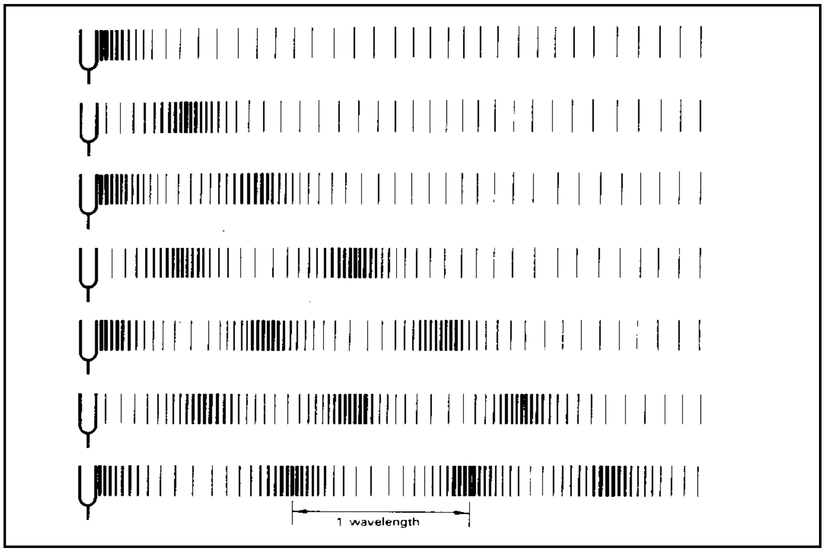
Examples of illustrations may include:
- ***“Slinky” waves*** - transverse and/or longitudinal (see PS-7.2). A wave in a “slinky” spring illustrates a mechanical disturbance caused by a force displacing one of the spring coils.



  - The energy of a wave in a “slinky” spring will pass from the point on the spring where a coil has been displaced to the end of the slinky.
  - The medium consists of the slinky coils.
  - The coils either move back and forth parallel to the length of the spring, or back and forth perpendicular to the length of the spring

- After the wave passes, the coils return to approximately the position where they were before the wave passed.

- ***Sound waves:***



The energy of the wave transmits from the tuning fork out in all directions. The shape of the wave will approximate the shape of concentric spheres.

  - A sound wave requires a medium through which it travels.
  - A sound wave is a longitudinal mechanical disturbance caused by a force displacing molecules in the medium through which it passes.
  - A sound wave's energy travels out in all directions from a vibrating object.
  - A sound wave travels through the medium. The particles of the medium remain where they were originally, but the wave energy moves from one place to another.
    - The particles of the medium move back and forth, parallel to the direction of the wave.
    - After a sound wave passes, the particles of the medium continue moving in approximately the same area where they were before the wave passed.

- ***Light waves***
  - Light waves do not need a medium through which to travel.
  - Light waves are transverse waves.
  - Light waves (or other electromagnetic waves) are energy that can be transmitted without mechanical disturbance of the particles of a medium
  - Light waves (and other electromagnetic waves) travel in straight lines in all directions from the source of the light as long as the medium does not change.
  - Light waves can transmit energy through empty space as from the Sun or stars.
  - The energy of the light wave travels from one place to another, but the particles of the medium, if there is one, remain in approximately the same area where they were before the wave passed.

Nature and Properties of Waves

PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

Students should understand that all waves transfer energy from place to place. If the wave moves though a medium, the particles of the medium can be displaced in a variety of ways (such as parallel or perpendicular to the wave motion), but they are not transported with the energy of the wave.

Assessment Guidelines:
The objective of this indicator is to *illustrate* ways that the energy of waves is transferred, therefore, the primary focus of assessment should be to find specific illustrations (drawings, diagrams, or word descriptions) or use illustrations that show that the energy is being transferred in a variety of waves, transverse and longitudinal/compressional, and how the transfer of energy is different from the displacement of particles in the medium.

In addition to *illustrate*, students should be able to

- *Identify* transverse and longitudinal waves from illustrations;
- *Compare* transverse and longitudinal wave particle motion and energy transfer direction;
- *Summarize* the characteristics of longitudinal/transverse waves.
- *Exemplify* transverse and longitudinal waves.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.2 Compare the nature and properties of transverse and longitudinal/compressional mechanical waves.
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Key Concepts:
Mechanical waves: Transverse waves, Longitudinal/Compressional waves
Wave properties: Crest, Trough; Compression, Rarefaction

Previous/Future knowledge: In the 8th grade students distinguished between mechanical and electromagnetic waves (8-6.2), and explained how scientists use seismic waves—primary, secondary, and surface waves—to determine the internal structure of Earth (8-3.2). In Physical Science students will consider particle movement within the medium to compare transverse and longitudinal waves.

It is essential for students to
- Understand that there are two types of waves, electromagnetic and mechanical.
  - Electromagnetic waves may travel through a medium but do not need a medium for transmission. Electromagnetic waves transfer energy through a medium or space. (Electromagnetic waves will be addressed in PS-7.5)
  - *Mechanical waves* must have a medium through which to move.
    - Mechanical waves transfer energy through the particles of a medium.
    - The particles of the medium move back and forth, but the wave (energy) itself is transmitted progressively from one place to another.
- Understand the <u>nature</u> of transverse and longitudinal mechanical waves.
  - In a ***transverse wave***, as the wave (energy) moves through the medium, the direction of the back and forth motion of the particles is perpendicular to the direction that the wave is moving.
    - Examples of transverse mechanical waves might include: Some "slinky" spring waves, secondary earthquake waves, and waves in the string of stringed instruments such as a guitar.
  - In a ***longitudinal wave*** (also called compressional), as the wave (energy) moves through the medium, the direction of the back and forth motion of the particles is parallel to the direction that the wave is moving.
    - Examples of longitudinal mechanical waves might include: Some "slinky" spring waves, sound waves, primary earthquake waves, shock waves from a sonic boom or explosion, and ultrasonic waves.
- Understand the <u>wave properties</u> of transverse waves - crests and troughs, and of longitudinal waves - compressions and rarefactions.
  - In a ***transverse wave*** the point of maximum displacement of the particles in a medium from the equilibrium position is called a *crest* or *trough*.
  - In a ***longitudinal wave*** the particles of the medium are pushed closer together to form a high pressure area called a *compression* and spread out to form a lower pressure area with fewer particles called a *rarefaction.*
- Understand that some waves cannot be classified as transverse or longitudinal waves
  - The motion of the particles in some waves can be described as circular. Surface water waves fall into this category.
  - In torsion waves the motion of the particles is a twisting motion.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

Misconception:
Students sometimes think that waves are one or two-dimensional. Many waves such as sound and light waves are often three-dimensional.

It is not essential for students to describe the motion of particles in waves that are not transverse or longitudinal waves, such as torsion waves or water surface waves.
Students should, however, be able to recognize these waves as non-examples if the motion of the particles in the medium is described.

Assessment Guidelines:
The objective of this indicator is to *compare* the nature and properties of transverse and longitudinal waves, therefore, the primary focus of assessment should be to give similarities and differences between these waves with regard to the movement of the particles in the medium, the direction that the wave moves, and the properties of the waves.

In addition to *compare*, students should be able to
- *Exemplify* or *Illustrate* transverse and longitudinal waves - give examples or draw or label illustrations which depict the motion of particles and the motion of the wave;
- *Classify* waves by determining which of the two types of waves (transverse or longitudinal) is being described based on the motion of particles and the motion of the wave;
- *Summarize* transverse and longitudinal mechanical waves by giving major points about the characteristics of these waves.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.3 Summarize characteristics of waves (including displacement, frequency, period, amplitude, wavelength, and velocity as well as the relationships among these characteristics).
Taxonomy Level: 2.4-B Understand Conceptual Knowledge

Key Concepts:
Displacement of particles
Frequency: Hertz
Period
Amplitude
Wavelength
Velocity - meaning speed

Previous/Future knowledge: In the 8th grade students "summarize factors that influence the basic properties of waves (including frequency, amplitude, wavelength, and speed)" (8-6.1).
In Physical Science the students expand on this idea and summarize the relationships among these characteristics. Students will understand the relationship of the movement of the particles in the medium and the wave characteristics. In Physical Science the concept of displacement is introduced both with respect to the wave energy and with respect to the movement of the particles in the medium. -

It is essential for students to
- Understand characteristics of waves can be explained in terms of how the particles in the medium behave.
  - ***Amplitude***
    - The amplitude is the greatest displacement of the particles in a wave from their equilibrium (rest) position.
    - In a transverse wave amplitude is measured from the equilibrium or rest position of the medium to a crest or trough.
  - ***Displacement***
    - Displacement with respect to waves will refer to the displacement of the particles in the medium.
    - This quantity has magnitude and direction.
    - It is the distance of a vibrating particle from the midpoint of its vibration. (Displacement is used in discussing amplitude and interference of mechanical waves.)
  - ***Frequency***
    - The frequency of the wave is the number of complete cycles (or vibrations) the particles go through per second or the number of waves that pass a point per second.
    - The unit for frequency is *Hertz,* which is one vibration per second or one cycle per second or one wave per second.
    - The frequency and the wavelength are inversely related. When the frequency gets higher the wavelength gets shorter.

- ***Period***
  - The period of a wave is the time for one cycle (or vibration) or the time for one complete wave to pass a point.
  - The period is usually measured in seconds.
  - The period and the frequency are inversely related. An increase in frequency would result in a decrease in period.
- ***Wavelength***
  - Wavelength of a wave is distance between a point in a wave and the next similar (in phase) point.
  - In a transverse wave the wavelength can be measured from a crest to the next crest or from a trough to the next trough.
  - In a longitudinal wave the wavelength can be measured from point in the compression to a similar point in the next compression or from a rarefaction to a similar point in the next rarefaction.

Teacher Note: Since most longitudinal waves (such as sound waves) are not visible, the wavelength is often measured by indirect means.

- ***Velocity/Speed***
  - The velocity/speed of the wave is a function of the medium and the type of wave and will not change unless the characteristics of the medium or type of wave changes.
  - Changes in frequency or wavelength do not affect the velocity/speed (of mechanical waves). When one of these increases the other decreases and the product of the two is a constant, which is the velocity/speed.
  - When the medium changes, the speed of waves changes. Examples may include: Sound travels faster in steel than in air. Sound travels faster in warm air than cooler air. Light travels faster in air than in glass. Transverse waves travel slower in a heavy rope than in a light rope.

Teacher note: For purposes of this course wave velocity/speed will be treated as a scalar quantity. No direction needs to be indicated.

It is not essential for students to

- Know the speed of waves in certain media;
- Explain why waves travel slower in one specific medium than another.

Assessment Guidelines:
The objective of this indicator is to *summarize* the characteristics of waves, therefore, the primary focus of assessment should be to give major points about each characteristic of a wave and the relationships among these characteristics.

In addition to *summarize*, assessments may require that students

- *Compare* the characteristics of different types of waves;
- *Exemplify* and *illustrate* characteristics of different types of waves;
- *Identify* wave characteristics from a description or diagram;
- *Interpret* diagrams to determine wave characteristics.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.4 Use the formulas $v = f\,\lambda$ and $v = d/t$ to solve problems related to the velocity of waves.
Taxonomy Level: 3.2-C Apply Procedural Knowledge

Key Concepts:

Wave speed	Frequency
Hertz	Wavelength

Previous/Future knowledge: In the 8th grade students used the formula for average speed, $v = d/t$, to solve real-world problems (8-5.2). The students used this formula for finding speed of objects. Students have not previously used these formulas applied to waves. In Physical Science students will use the formulas $v = f\,\lambda$ and $v = d/t$ in different and unfamiliar situations to solve problems relating to all of the variables in the indicator with respect waves.

It is essential for students to
- Solve problems for any variables in the two equations, $v = f\,\lambda$ ($f = v/\lambda$ or $\lambda = v/f$) and $v = d/t$ ($d = v\,t$ or $t = d/v$), using experimental data.
- Use dimensional analysis to determine the proper units. Examples may include:
  - If distance is given in meters and time is given in seconds, then velocity will be m/s.
  - If frequency is given in hertz and wavelength is given in meters, then velocity will be m/s.
  - If velocity is given in km/h and time is given in hours then distance will be kilometers.
- For math problems involving the wave standard in Physical Science, the quantities are treated as scalar quantities (have size or amount not direction) rather than vector quantities that would involve direction.
  - For the purposes of the wave problems, "v" will represent the scalar quantity speed.
  - For the purposes of the wave problems, "d" will represent the scalar quantity distance.

It is not essential for students to
- Solve problems involving both formulas - finding a factor in one formula to use in the other formula;
- Solve vector problems (speed and direction) involving waves.

Assessment Guidelines:
The objective of this indicator is to *use* the formulas $v = f\,\lambda$ and $v = d/t$ to solve problems, therefore, the primary focus of assessment should be to apply the correct procedure to mathematically determine one of the variables in the formulas $v = f\,\lambda$ and $v = d/t$. −

In addition to *use*, assessments may require that students
- *Use* dimensional analysis to determine correct units;
- *Recognize* symbols and units for wave velocity formulas.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.5 Summarize the characteristics of the electromagnetic spectrum (including range of wavelengths, frequency, energy, and propagation without a medium).
Taxonomy Level: 2.4-B Understand Conceptual Knowledge

Key Concepts:
Electromagnetic spectrum
Visible spectrum
Propagation without a medium

Previous/Future knowledge: In the 8^{th} grade students compared the wavelength and energy of waves in various parts of the electromagnetic spectrum (including visible light, infrared, and ultraviolet radiation) (8-6.8). Physical Science requires that students expand their concept of the nature of electromagnetic radiation. Students will summarize different types of radiation within the spectrum.

It is essential for students to understand
- That there is a wide range of frequencies and wavelengths of electromagnetic waves. The entire range of frequencies is called the *electromagnetic spectrum*.
- The relative positions of the different types of electromagnetic waves on the spectrum.
  - Students should know the order of electromagnetic waves from low frequency to high frequency: radio waves, microwaves, infrared radiation, visible light (red, orange, yellow, green, blue, violet), ultraviolet, X-rays, and gamma rays.
- Understand that the energy of electromagnetic waves is directly proportional to the frequency. When listed in order from lowest energy to highest energy, the list is the same as when listed from lowest frequency to highest.
  - Electromagnetic waves with higher frequencies than visible light also have more energy. This is why ultraviolet light can burn your skin, and X-rays and gamma can damage tissues.
  - Electromagnetic waves with lower frequencies than visible light and have less energy than visible light.
- Understand that the higher frequency electromagnetic waves have shorter wavelengths.
- Understand that wavelengths vary greatly from very long wavelengths (many meters) to very short wavelengths (the size of atomic nuclei).
- Understand that electromagnetic waves travel in space with no medium or may travel through a transparent medium.
  - All types of electromagnetic waves travel at the same speed in a vacuum.
  - Electromagnetic waves slow down when they move from a vacuum to a transparent medium.
  - Electromagnetic waves are transverse waves.

It is not essential for students to
- Explain the nature of the oscillating electric and magnetic fields in electromagnetic waves;
- Give the specific numbers for the wavelength or frequency range of different types of electromagnetic waves;
- Understand the concept of photons of energy, but this may be a good class discussion depending on the level of the students;
- Understand how different spectra (continuous, bright line/emission, dark line/absorption) are produced.

Assessment Guidelines:
The objective of this indicator is to *summarize* the characteristics of the electromagnetic spectrum, therefore, the primary focus of assessment should be to give major points about the wavelengths, frequency, energy, and propagation without a medium for the different types of electromagnetic radiation.

In addition to *summarize*, assessments may require that students:
- *Compare* the frequency, wavelength, and energy of different types of electromagnetic radiation;
- *Infer* characteristics of a type of electromagnetic radiation from its position in the spectrum;
- *Exemplify* characteristics and types of electromagnetic radiation;
- *Illustrate* or use illustration to show characteristics of waves at different positions on the electromagnetic spectrum.

Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.6 Summarize reflection and interference of both sound and light waves and the refraction and diffraction of light waves.
Taxonomy Level: 2.4-B Understand Conceptual Knowledge

Key Concepts:
Wave behaviors: Reflection, Refraction, Diffraction
Constructive interference, Destructive interference
Concave lens, Convex lens
Law of reflection, Plain mirrors

Previous/Future knowledge: In the 8th grade students summarized the behaviors of waves (including refraction, reflection, transmission, and absorption) (8-6.4); explained hearing in terms of the relationship between sound waves and the ear. (8-6.5); explained sight in terms of the relationship between the eye and the light waves emitted or reflected by an object (8-6.6); and explain how the absorption and reflection of light waves by various materials result in the human perception of color (8-6.7). In Physical Science the students will expand the ideas of reflection and refraction of light and reflection of sound. The students will be introduced to the ideas of constructive and destructive interference of sound and light waves. The students will also be introduced to the concept of diffraction of light waves.

It is essential for students to
- Understand that waves can interfere with each other when they pass through a medium simultaneously. The result of the combination of the waves when they pass through the medium simultaneously can show constructive and/or destructive interference.
  - Interference may be *constructive*:
    - A crest will interfere with another crest constructively to produce a larger crest and a trough will interfere with another trough to produce a larger trough.
    - Compressions interfere constructively with each other as do rarefactions.
  - Interference may be *destructive*:
    - A crest will interfere with a trough to lessen or cancel the displacement of each.
    - Compressions interfere with rarefactions to lessen or cancel the displacement of each
  - The individual waves are not affected by the interference and will continue on as if nothing has happened.

Sound waves
It is essential for students to
- Understand that sound is a longitudinal mechanical wave, requires a medium, and can be produced by vibrating objects.
- Understand that sound, like other waves, *reflects* (bounces off a surface it cannot go through). Sound produces echoes when it bounces off hard surfaces.
- Understand that sound waves *interfere* with each other changing what you hear.
  - Destructive interference makes sounds quieter; constructive interference makes sounds louder. This is because amplitude of a wave is what is affected by interference and a sound wave's amplitude is heard as loudness.
  - Sound waves reflect in tubes or some musical instruments to produce standing waves which reinforce sound through constructive interference to make the sound louder.

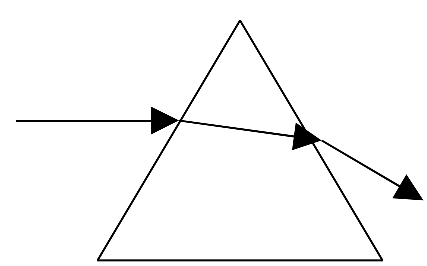
Nature and Properties of Waves

PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

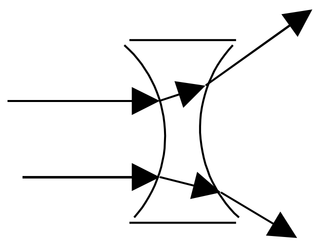
Light waves

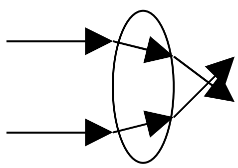
It is essential for students to

- Understand that light waves *reflect*:
  - When light rays reflect they obey the "*Law of Reflection*". The angle of incidence is equal to the angle of reflection.
    - The angle of incidence is the angle between the incident ray and a line normal (perpendicular) to the surface at the point where the light strikes.
    - The angle of reflection is the angle between the reflected ray and the normal line.
- Understand that light waves *reflect in plain mirrors* to produce images.
  - The image appears as far behind the mirror as the object is in front of it.
  - The image and the object appear to be same size.
  - The image is upright.
- Understand that light, like other waves, can *diffract.*
  - *Diffraction* is the bending of a wave around a barrier or around the edges of an opening.
    - Waves with a longer wavelength diffract more readily. In order to observe light diffraction the barriers or openings must be small.
    - When light waves diffract interference patterns can often be observed.
- Understand that light waves can *interfere* to produce interference patterns.
  - Light waves can interfere constructively and destructively.
    - When light waves interfere, a pattern is often seen with light and dark areas created by constructive and destructive interference. The amplitude of a light wave is observed as brightness. Brighter areas show constructive interference and darker areas show destructive interference.
    - At other times light waves interfere to produce a color pattern. When a color of light interferes destructively, we will not see that color. We will see the colors that are not interfered with destructively.
  - Light waves can reflect off the bottom and top surfaces of thin film, such as oil on water or bubbles, and produce a color pattern due to interference.
  - Light wave can diffract through small slits or around lines to produce light and dark patterns or color patterns due to the interference of light waves.
- Understand that light, like other waves, can *refract*.
  - Waves refract when they change direction upon entering another medium. In order to refract the wave must:
    - Change speed when it hits the new medium and
    - The wave must strike the new medium at an angle other than perpendicular.
  - Light waves refract when they enter a different medium at an angle other than perpendicular and change speed.
  - Students should be able to predict the way that the light rays will bend.
    - In the diagram at the right, light slows down when it enters the prism and bends down when it strikes at this angle.
    - When light exits the prism at the right, it speeds back up and bends down again.



- When white light enters another medium such as a prism and refracts the colors may spread out. This is because the violet end of the spectrum slows down more than the red end and therefore bends more.
- Lenses may be a concave (diverging) lens or convex (converging) lens.
- Students should be able to draw the resulting rays as light passes through each type of lens.





It is not essential for students to
- Understand the distance an object must be placed to produce certain images with different types of lenses or mirrors or the sizes of those images;
- Understand concave and convex mirrors;
- Understand focal length;
- Understand that light waves form real or virtual images of different sizes when passing through lenses;
- Understand how sound waves are made by musical instruments.

Assessment Guidelines
The objective of this indicator is to *summarize* the concepts of reflection, refraction, diffraction and interference for light waves and reflection and interference for sound waves, therefore, the primary focus of assessment should be give major points about these wave behaviors related to light and sound waves.

In addition to *summarize*, assessments may require that students
- *Compare* the behavior of light waves in different situations of reflection or refraction;
- *Infer* how light waves reflect, refract or interfere;
- *Infer* what will be heard when sound interferes or reflects;
- *Exemplify* behavior of light or sound waves in different situations or effects of that behavior;
- *Illustrate* light wave behavior when it encounters concave or convex lenses or a prism.

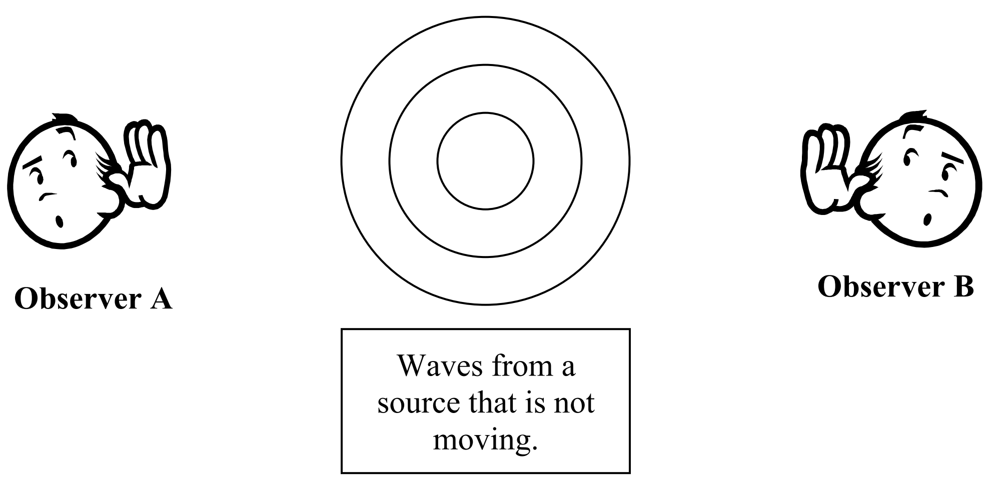
Nature and Properties of Waves
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.7 Explain the Doppler effect conceptually in terms of the frequency of the waves and the pitch of the sound.
Taxonomy Level: 2.7-B Understand Conceptual Knowledge

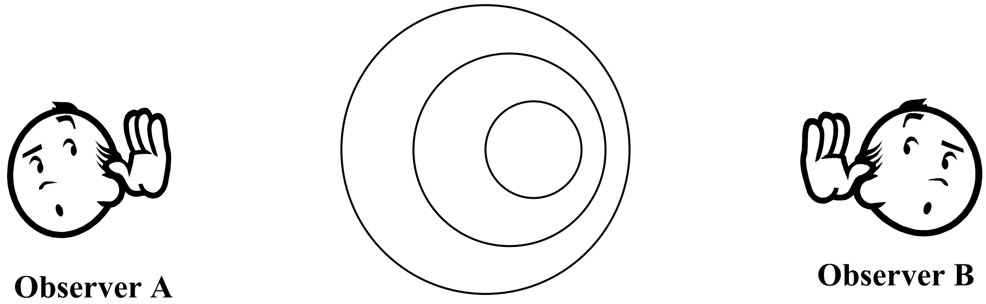
Key Concepts:
Doppler Effect
Frequency, Wavelength, Pitch

Previous/Future knowledge: In the 8th grade students explained hearing in terms of the relationship between sound waves and the ear (8-6.5). In Physical Science the students will expand their concept of wave frequency and how they hear frequency of sound as pitch by explaining the Doppler effect.

It is essential for students to
- Understand that the *Doppler effect* is an apparent frequency shift due to the relative motion of an observer and a wave source.
- Understand the relative motion of a wave source and an observer.
    - A Doppler shift occurs when a wave source is moving toward an observer or away from the observer**.**
    - A Doppler shift also occurs when the observer is moving toward or away from the wave source.
    - There is no shift when the source and observer are not moving toward or away from each other.



The example above shows a wave source and observers that are not moving relative to one another. If the wave source in the example is a sound wave, observer A and observer B would hear the same pitch (frequency) that the source is producing.



Waves from a source that is moving to the right.

The example above shows a wave source that is moving toward observer B. If the wave source in the example is a sound wave then observer B will hear a higher pitch (frequency) and observer A will hear a lower pitch (frequency) than the source is actually producing.

Situation – wave source moving toward or away from an observer:

- As a wave source approaches an observer, the observer perceives a higher frequency than the source is producing. Wavelengths are shorter and the frequency is higher in front of a moving source.
  - The source of the wave is catching up with the wave in front of it. When it produces the next pulse the resulting wavelength is shorter. A shorter wavelength means that there will be a higher frequency
  - If the wave is a sound wave, the observer will perceive a pitch that is higher than the pitch produced by the source.
- When the wave source is moving away from the observer, he/she will perceive a lower frequency than the source in producing. Wavelengths are longer and the frequency is lower behind a moving source.
  - The source of the sound is moving away from the wave behind it. When it produces the next pulse the resulting wavelength is longer. A longer wavelength means that there will be a lower frequency.
  - If the wave is a sound wave, the observer will perceive a lower pitch that the source is producing

Situation – the observer moving toward or away from the wave source:

- When the observer is moving toward a wave source, he/she would perceive a higher frequency than the source is producing. The observer encounters waves more often than the source is producing them.
  - If the observer encounters more waves, he/she perceives a higher frequency.
  - The observer would perceive a higher pitch in the case of sound waves.
- When the observer is moving away from a wave source he/she would perceive a lower frequency than the source is producing. The waves would have to catch up with him and he/she would encounter fewer waves.
  - If the observer encounters fewer waves he/she perceives a lower frequency.
  - The observer would perceive a lower pitch in the case of sound waves.

Nature and Properties of Waves

PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

Misconception: Students sometimes say that the Doppler effect is observed when a source of sound and an observer move toward each other the sound gets louder and as they move away from each other the sound gets softer. While the observer will hear a louder and softer sound in these situations, this is not the Doppler effect.

It not essential for students to understand why a red shift or blue shift occurs in light.

Assessment Guidelines:
The objective of this indicator is to *explain* the Doppler effect in terms of frequency and pitch, therefore the primary focus of assessment should be to construct cause and effect models that show the effect each variable has on the perceived frequency of waves and on the pitch of sound. Assessments should be based on the fact that the relative motion between a source of waves and an observer will affect the frequency at which waves are encountered. An observer will perceive a different frequency (pitch with sound) than the frequency of the source.

In addition to *explain*, assessments may require that students

- *Identify* the frequency that the listener observes in different situations relative to the frequency that the source is producing or the pitch heard by different observers in different locations with respect to the wave source;
- *Summarize* how different situations affect the perception of relative pitch (frequency);
- *Infer* from situations the relative pitch that the listener will observe;
- *Exemplify* situations which will produce the Doppler effect with sound waves.